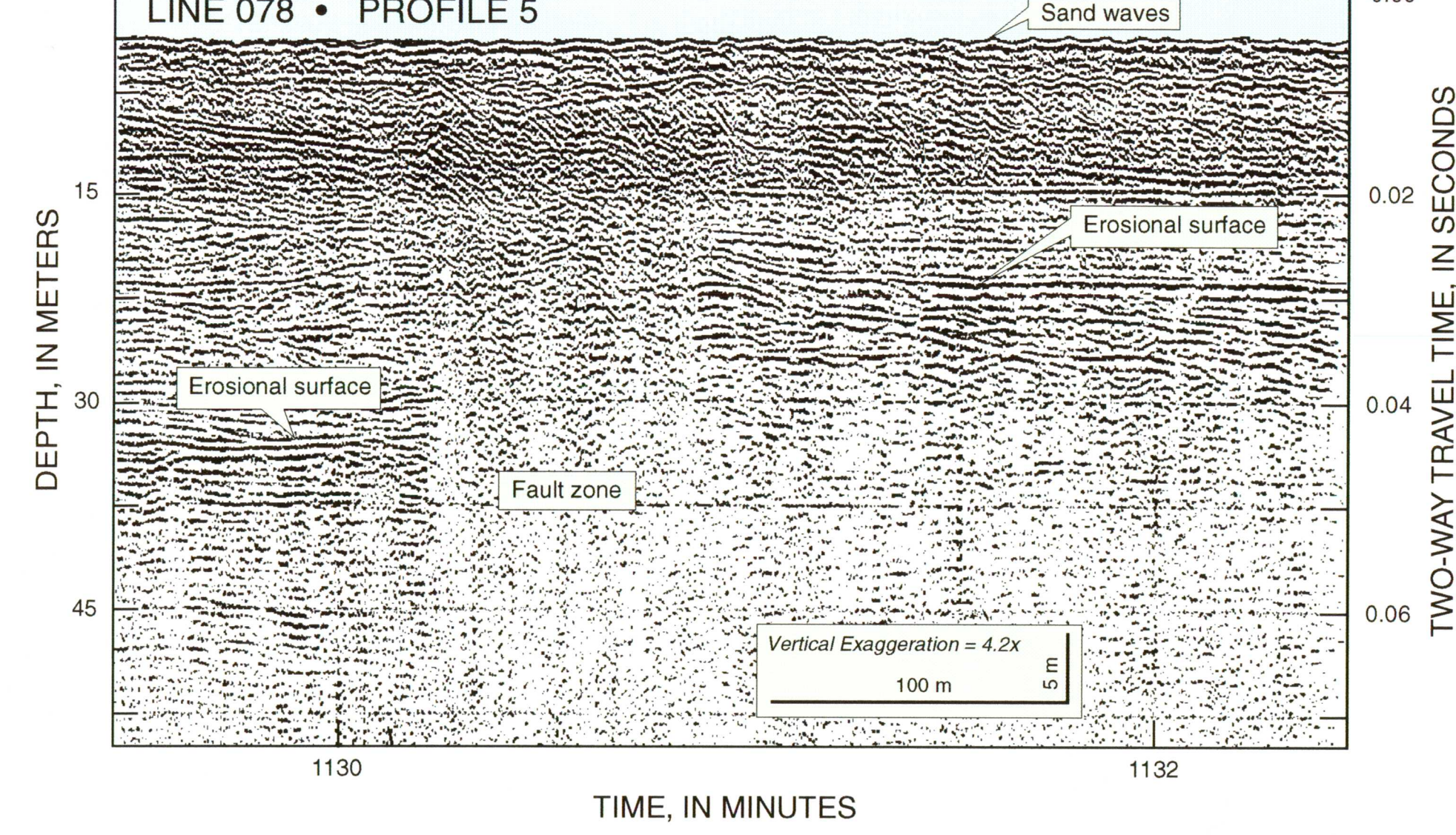
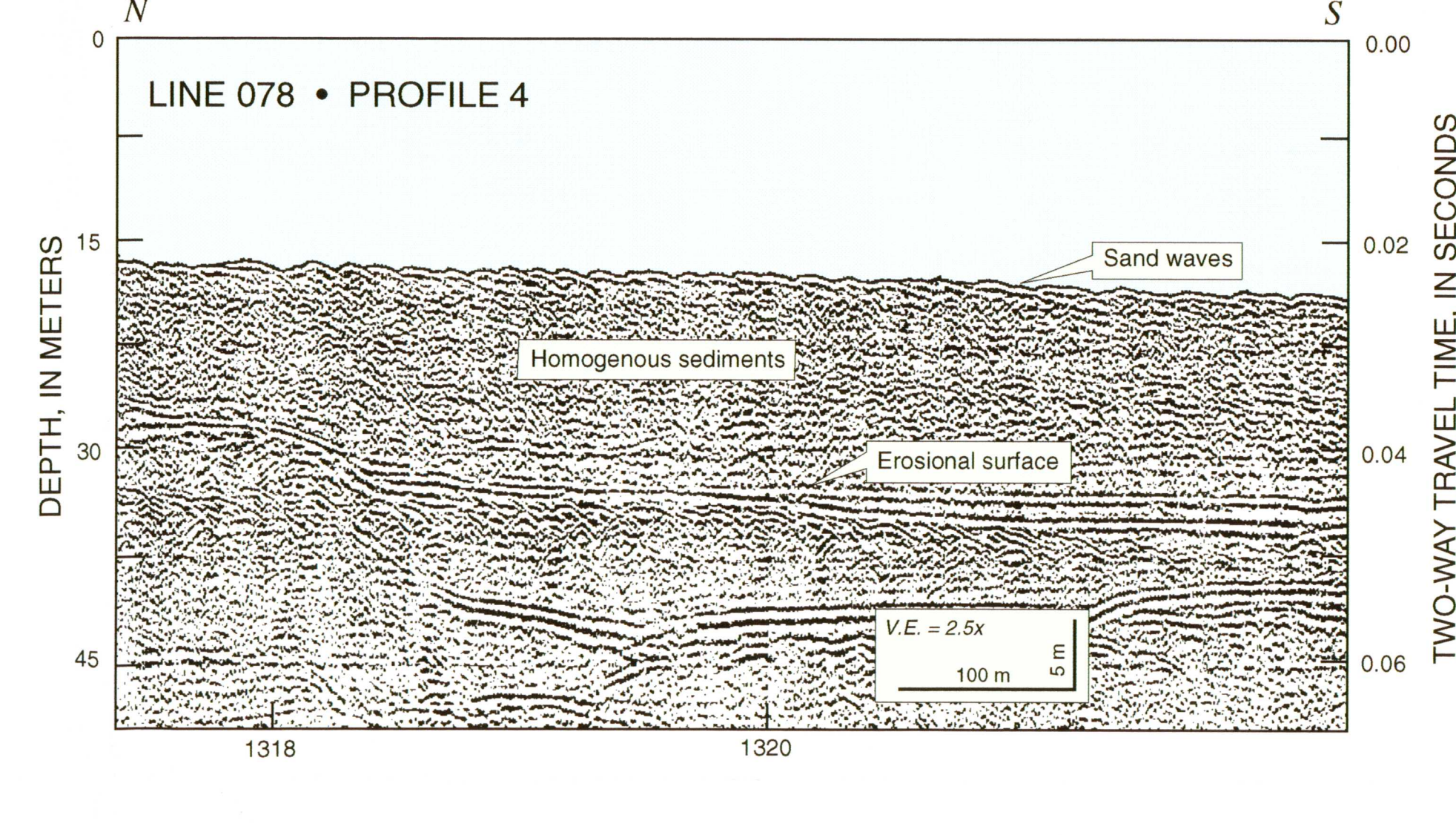
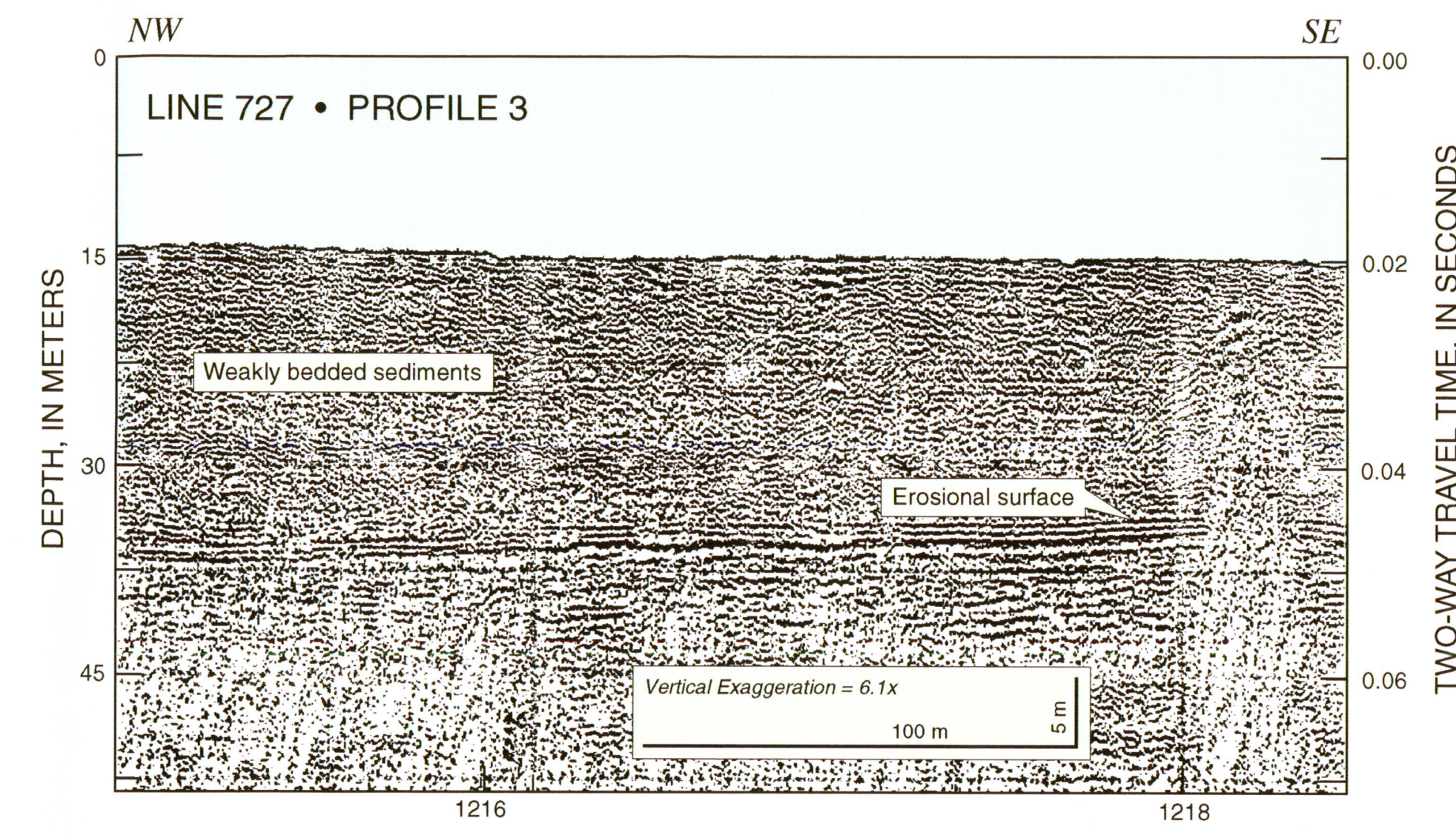
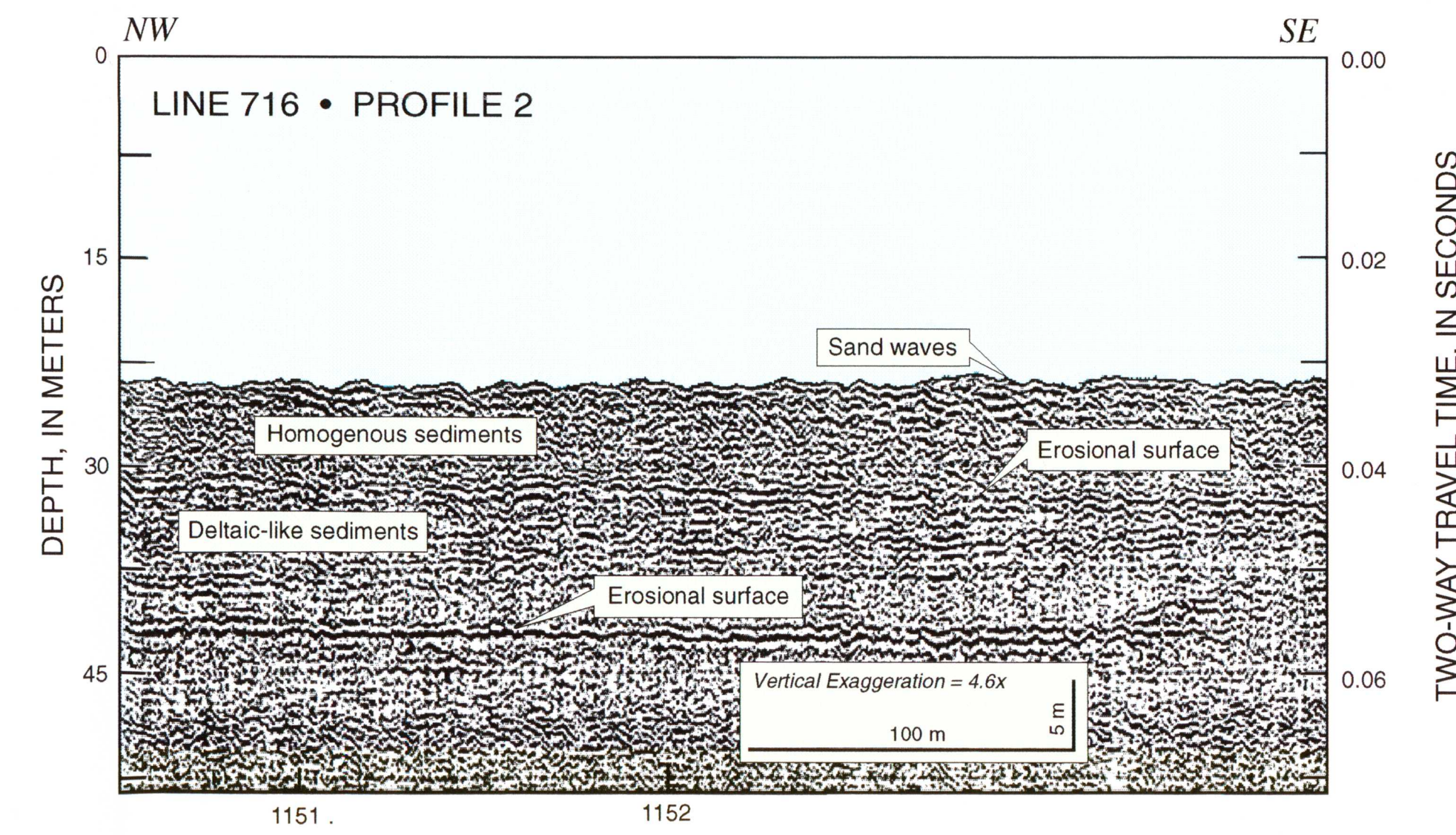
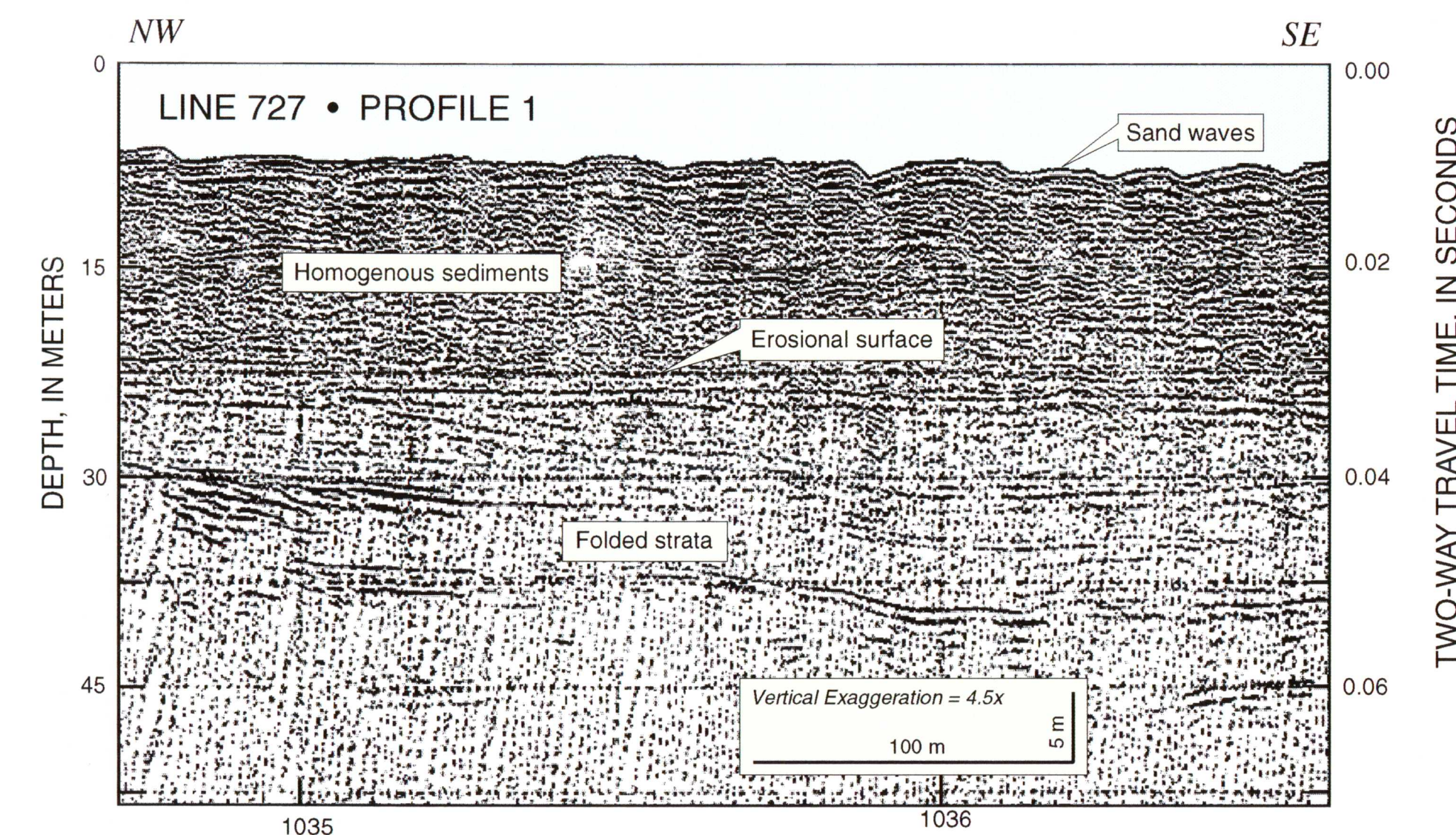
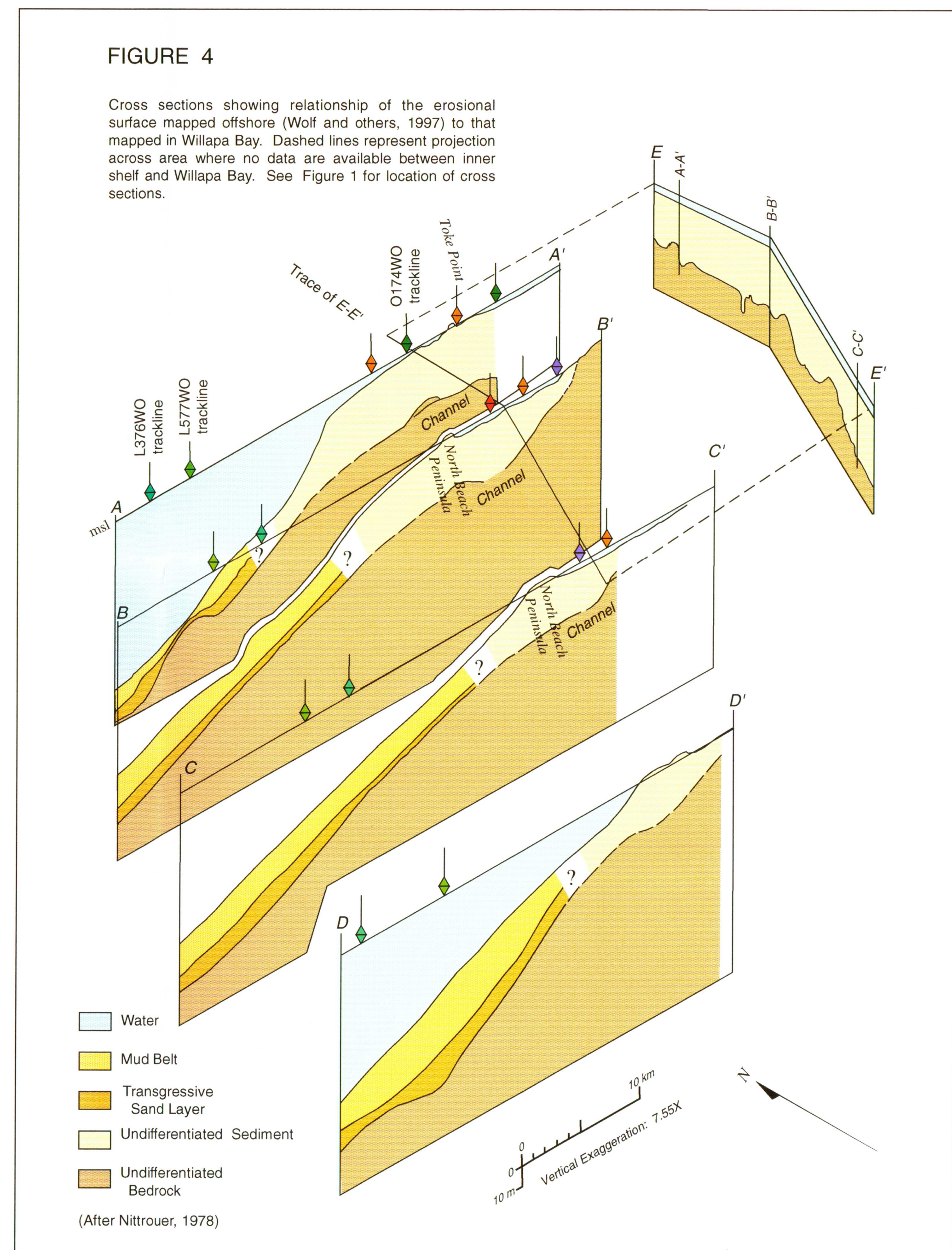
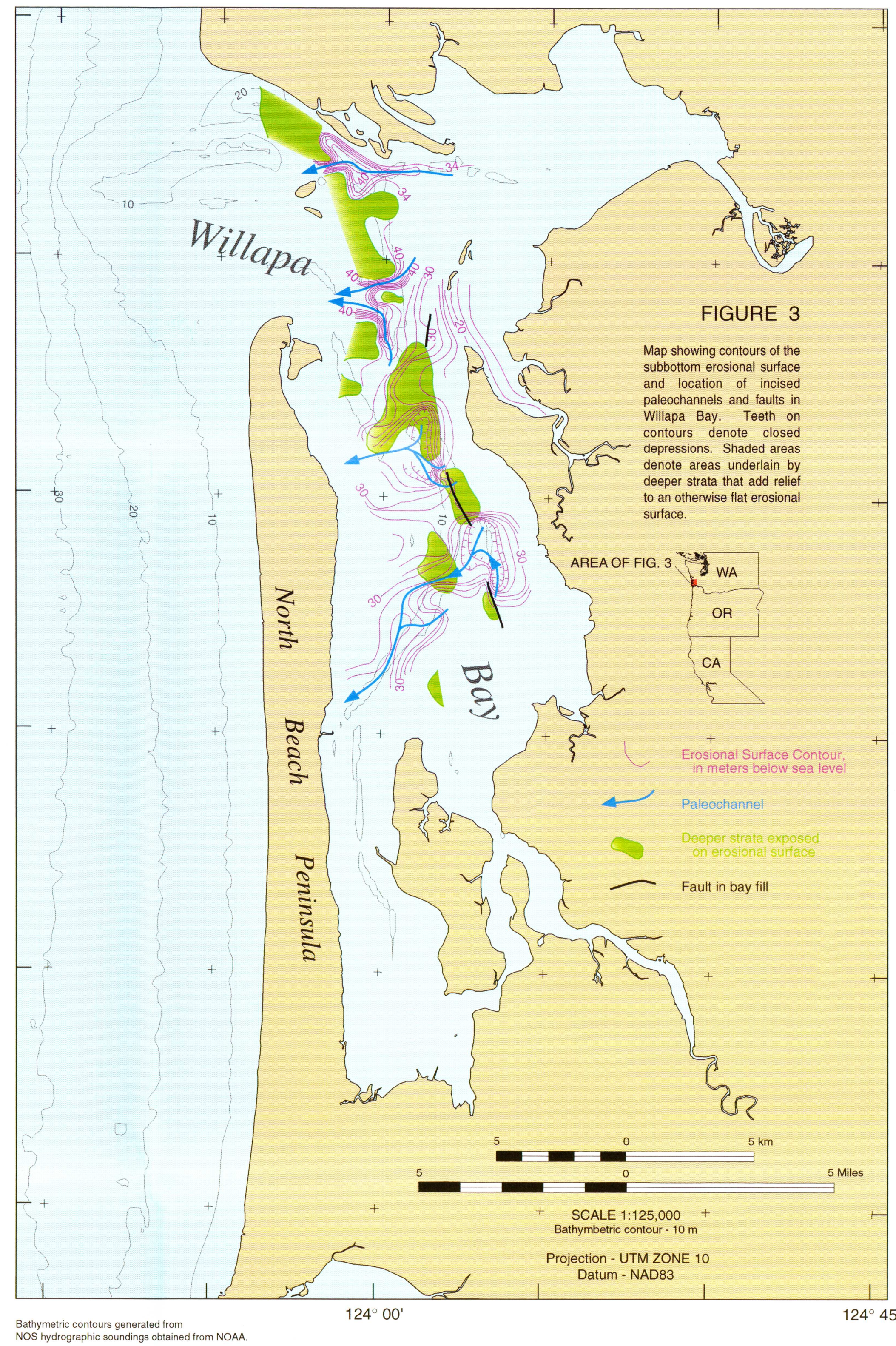
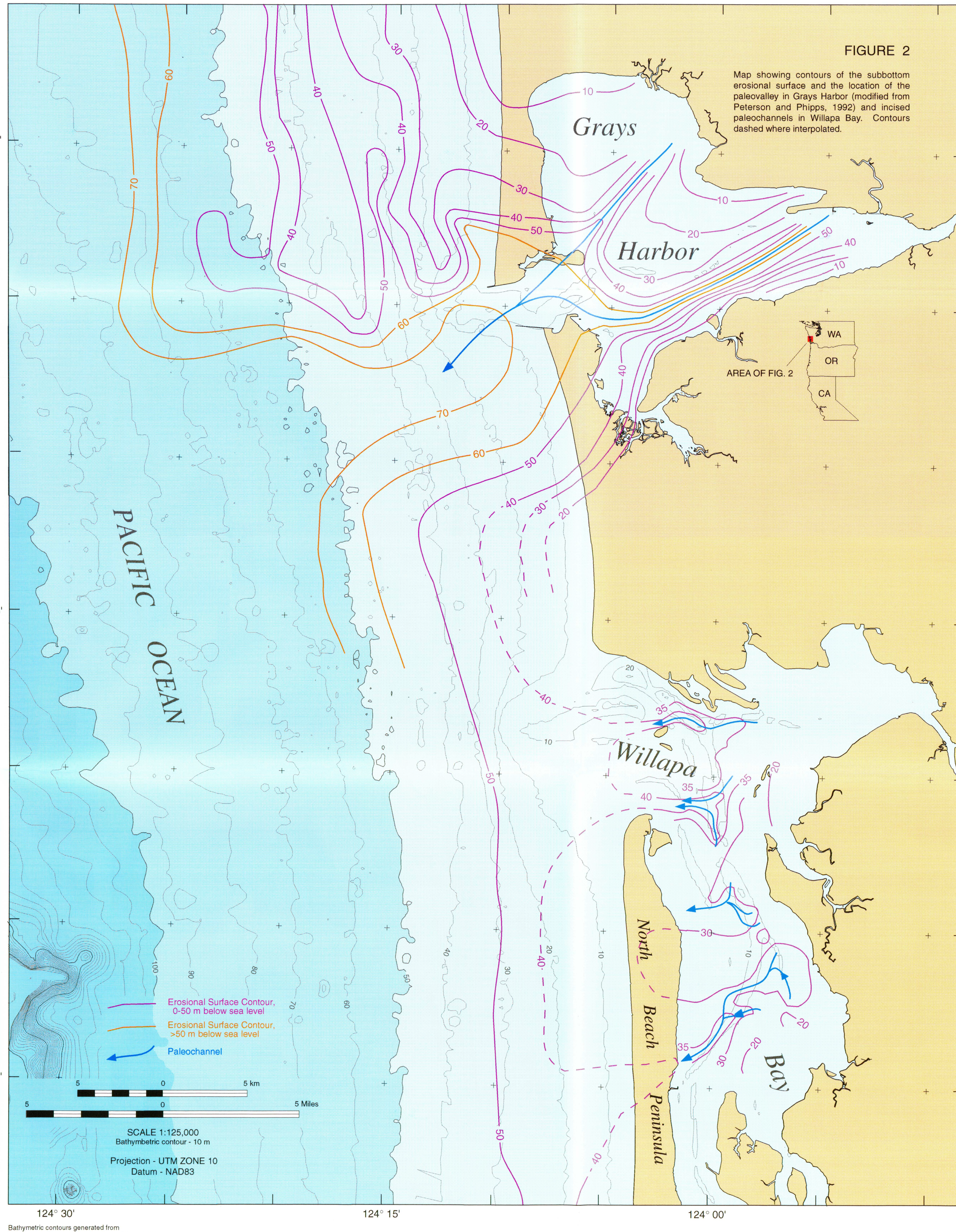
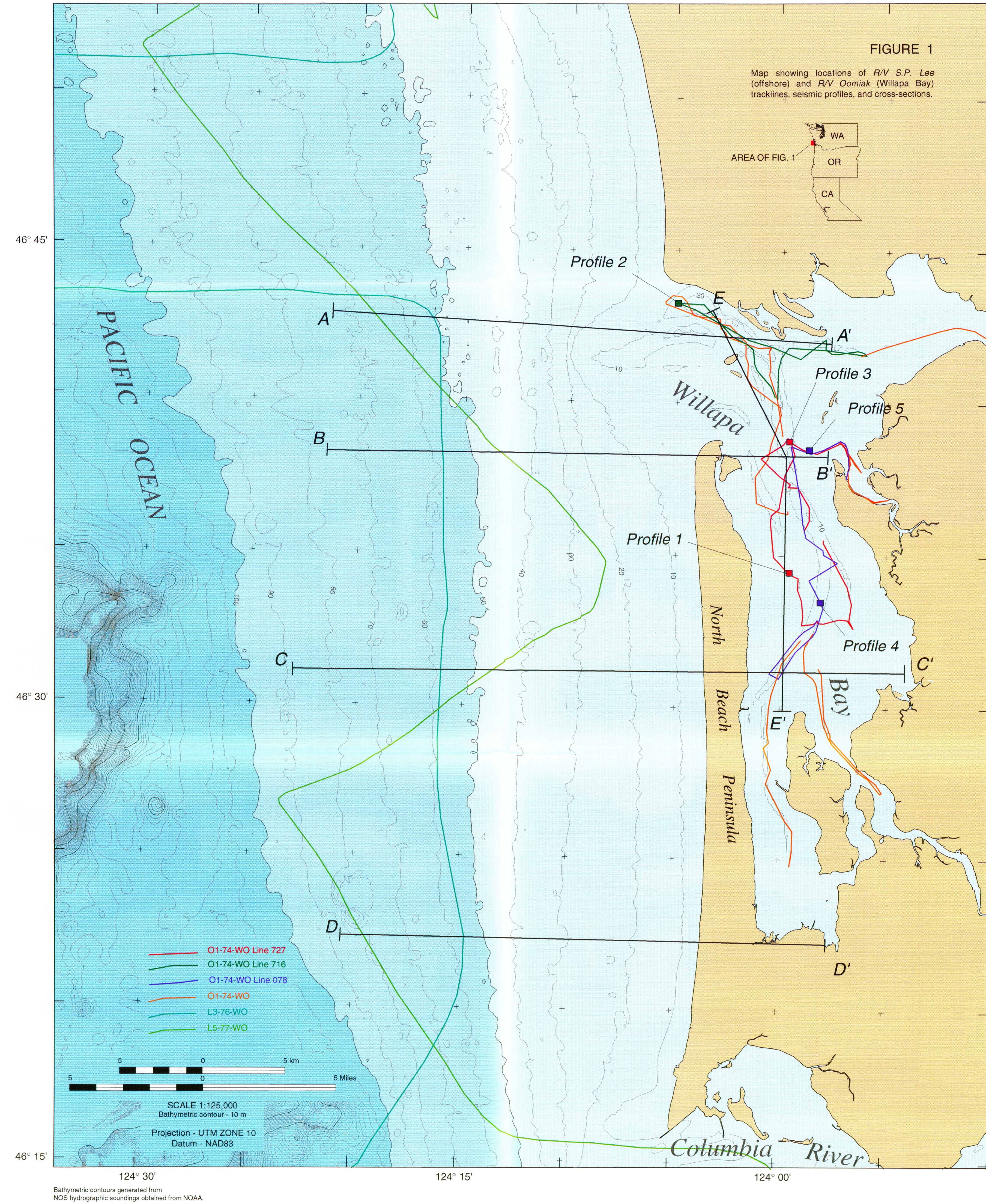


INVESTIGATIONS OF LATE QUATERNARY GEOLOGIC FEATURES IN WILLAPA BAY, WASHINGTON

by
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INTRODUCTION

Geologic reconnaissance maps of Willapa Bay, Washington present information intended to guide the planning of seismic-reflection and sample-core surveys conducted during 1998. The maps serve as preliminary field sheets to be updated following analysis of additional seismic-reflection data and dating of core samples. Major geologic features documented within Willapa Bay include a buried erosional surface, a linear bedrock high, and filled paleochannels that cut across the bedrock high. Wolf and others (1997) mapped an equivalent erosional surface on the inner shelf offshore Willapa Bay.

DATA COLLECTION AND QUALITY

These maps are derived from existing single-channel, seismic-reflection data collected during the 1974 USGS survey (O1-74-WO) using the R/V Omiak (Hill and others, 1981) (Fig. 1). The northeast and southern portions of Willapa Bay and the bay entrance lack sufficient data to map the geometry of the erosional surface or the thickness of unconsolidated sediment. Shallow water depths in Willapa Bay restricted data collection to tidal channels that primarily trend north-south. Nearshore single-channel, seismic-reflection data were collected during the 1976 and 1977 USGS geophysical surveys (L3-76-WO, L5-77-WO) using the R/V S.P. Lee (Fig. 1). The Omiak cruise acquired seismic-reflection data using a towed Unicom seismic system. The S.P. Lee cruises used an internally mounted Unicom system. All data sets were recorded on analog graphic recorders. Omiak seismic data were recorded at a 1/4-second scan rate (107.5-m scale) and the S.P. Lee data were recorded at 1/2-sec scan rate (375-m scale).

S.P. Lee data quality are average; Omiak data quality ranged from average to poor. Selected examples of seismic-reflection profiles from the Omiak data set (Profiles 1-5) display the data quality and depict characteristics of the erosional surface within Willapa Bay, the seismic stratigraphy above and below this surface, and other significant features. Locations of these profiles are shown in Fig. 1. Penetration depth for the Omiak Unicom system was about 50 m, with nominal resolution of 1-2 m at the bay floor and 1 m or less resolution in the subsurface. S.P. Lee Unicom data

penetrated about 75 m, with a resolution of 1-2 m at the seafloor and in the subsurface. Depths to the prominent erosional surface were calculated from two-way travel times using 1500 m/s seismic velocity. Variations between cruises in penetration depth, resolution, and data quality for each data set result primarily from changes in surficial sediment lithology, bedrock lithology, and sea state. Accuracy in ship's location along track differed as a result of differences in the precision of the navigation equipment employed. Offshore accuracy is approximately 1/4 nautical mile. In Willapa Bay, location of tracklines was largely controlled by channel position and water depth.

OBSERVATIONS

We contoured a prominent subsurface unconformity within Willapa Bay using modern sea level as the plane of reference. In Fig. 2, we also include contours of a similar erosional surface within Grays Harbor (Peterson and Phipps, 1992) to the north and contours of a prominent surface within the inner shelf (Wolf and others, 1997) to the west. In Fig. 3, a 2-m contour interval depicts the complex morphology of the erosional surface, the location of paleochannels, closed depressions and faults where bay fill, and areas where underlying strata give relief to the erosional surface. We also constructed four east-west cross sections and one north-south cross section (Fig. 1) to show the inferred relationship between the erosional surface offshore (Wolf and others, 1997) and the one mapped beneath Willapa Bay (Fig. 2).

The contour maps display several significant morphologic and structural features including:

1. The unconformity shown on Figs. 2 and 3 is the deepest, most widespread erosional surface that can be traced throughout Willapa Bay using existing high resolution seismic-reflection data. Depths to this surface (below modern sea level) range from 14 m in the east to 46 m in the west. The surface can be traced throughout the northern two-thirds of the bay, from the bay entrance southward to approximately latitude 46°N. A profile from Line 727 (Profile 1) illustrates the generally flat nature of the erosional surface. Strata below the surface are somewhat deformed and have a heterogeneous seismic character, implying variations in lithology, in contrast to strata above the unconformity that appear to have a relatively homogeneous seismic character and exhibit little lateral continuity in seismic reflectors.

2. A general shallowing of this surface from west to east suggests the surface may crop out onshore (Fig. 4, Cross section B-B'). Upper Pleistocene marine strata exposed onshore and in some of the active tidal channels within Willapa Bay (Phillips, 1998, oral commun.) are consistent with an eastward-shallowing erosional surface.

3. A unit of older, more erosion-resistant strata underlies portions of the erosional surface and adds relief to the otherwise relatively smooth surface. A profile from Line 078 (Profile 4) exhibits this localized relief. These local areas (shown in green on Fig. 3) where older strata have been structurally elevated to form the erosion surface, display a north-south linear trend in the subsurface, 25-35 m below sea level. This structural high parallels the present North Beach Peninsula shoreline to the west, and abuts a north-south trending topographic high just north of the entrance to Willapa Bay.

4. In contrast to the Peterson and Phipps (1992) study of Grays Harbor, we find no evidence for a deep paleochannel near the mouth of Willapa Bay (Fig. 2). Instead, a series of small incised channels is observed at the entrance to Willapa Bay and east of North Beach Peninsula. These buried channels originate east of the linear "bedrock" high and cut westward through the high to depths of 40-45 m below present sea level (Fig. 3). These paleochannels do not align with present-day channels, implying that channel locations have migrated over time.
5. Fig. 3 shows a sizable channel that trends southwest at latitude 46°N and projects beneath North Beach Peninsula. This channel, and several channels to the north and west, probably continue beneath North Beach Peninsula and the present entrance to Willapa Bay, and extend onto the inner shelf. The largest channel may grade to the erosional surface mapped offshore (Wolf and others, 1997) (Fig. 2) and projects towards a buried channel observed 115 m below sea level, 22 km to the southwest (Wolf and others, 1997).

6. Two closed depressions (Fig. 3) within the unconformity surface are located adjacent to the buried structural high. These depressions, bisected by paleochannels, may reflect localized channel erosion diverted by the erosion-resistant high.

7. In central Willapa Bay, a single fault strand is observed on several profiles and offsets the unconformity between 4 and 8 m, west-side-up. Four km to the south, a single fault strand bounds the southwest side of a depression within the unconformity (Fig. 3). This strand, southwest-side-up, sub-parallel the axis of the depression and suggests that fault displacement may have partially controlled development of the depression (Fig. 3). The erosional surface and underlying strata appear to be vertically offset approximately 5 m.

8. Faulted strata are also observed 5 km east of the tip of North Beach Peninsula (Fig. 3). Here, a 500-meter-wide fault zone appears to align with the eastern side of a depression within the erosional surface, suggesting that fault displacement may have partially controlled development of the depression. This zone displays a fault strand along its western margin, west-side-down, with approximately 4 m offset. Along the eastern margin, a fault strand displays 10-12 meters offset, west-side-up. Both the faults strands here and the ones to the south, as well as the adjacent depressions, align with the north-south structural high. A profile from Line 078 (Profile 5) depicts 10-12 m offset of the erosional surface and underlying deposits in the northern bay.

9. Strata above the erosional surface in Willapa Bay vary in character from units that display no internal reflectors in the southern bay area to units with discontinuous reflectors in the north. A profile from Line 727 (Profile 1) is representative of the seismic sequences found in the southern part of the bay. Few continuous reflectors are observed, implying that the strata are fairly homogeneous. The bed forms on the bay floor in this section display up to 1 m in relief. In the central portion of the bay (see Line 727, Profile 3), reflectors are more continuous than in the south indicating variation in seismic character and likely variation in lithology. Seismic reflectors are more pronounced in the northern portion of the bay (see Line 716, Profile 2). Here, gently inclined strata occur above the erosional surface suggesting that these facies represent an episode of lateral channel migration. This unit is mainly found along the southern terminus of the topographic high on the north side of the bay implying a local sediment source for this facies. The apparent strike of reflectors within this unit varies; however dips are predominantly to the southeast. Truncation of strata above this unit suggests the presence of a younger, localized erosional surface. This upper surface is overlain by homogeneous strata with few internal reflectors. Large bed forms up to 0.5 m in relief cover the bay floor in this area.

10. The late Quaternary unconformity mapped in the inner shelf (Nittrouer, 1976; Wolf and others, 1997) may correlate with the unconformity mapped in Willapa Bay based on similarity in character. Both surfaces are underlain by gently deformed strata and overlap by far-laying strata. Overlying unconformities in the shelf and in the bay appear to be local features and cannot be traced regionally. The projected elevation of the offshore surface 12 km eastward into Willapa Bay and 6 km eastward into Grays Harbor (Figs. 2 and 4) suggests that these surfaces are close in elevation and may be continuous. If continuous, the surface may have been cut during a major late Quaternary sea-level transgression. However, several minor glacio-eustatic cycles occurred during the late Quaternary, leaving the possibility that the offshore surface projects to a bay surface below the limit of available data (50 m). In this case, the Willapa Bay surface would represent a somewhat younger late Quaternary erosional event than the one offshore.

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